SPECIFICATION

TITLE OF THE INVENTION

5   RADIO COMMUNICATION APPARATUS

TECHNICAL FIELD

The present invention relates to a radio communication apparatus for carrying out communication with mobile radio

10   terminals.

BACKGROUND ART

As shown in Japanese patent application laid-open No. 8-316896/1996, for example, to cover the nondirectional 360°

15   range in a horizontal direction with four receiving antennas, a conventional radio communication apparatus carries out its receiving processing by generating four signals by combining outputs of the four receiving antennas to improve receiving characteristics. Another conventional radio communication

20   apparatus has a configuration that performs its receiving processing independently for individual receiving antennas, and combines the results.

With the foregoing configurations, the conventional radio communication apparatuses must have the demodulating sections

25   of the same number as the receiving antennas to perform the demodulation processing each. This offers a problem of increasing the size of the radio communication apparatus.

The present invention is implemented to solve the foregoing problems. Therefore it is an object of the present invention

30   to provide a radio communication apparatus capable of reducing

the number of the demodulating sections as compared with the number of the receiving antennas, thereby being able to reduce the size of the apparatus.

5   DISCLOSURE OF THE INVENTION

According to an aspect of the present invention, there is provided a radio communication apparatus that has first, second, third and fourth receiving antennas for receiving incoming radio waves, and carries out communication with mobile communication

10   terminals, the radio communication apparatus including: a received beam generating section for generating first and second received beams which are perpendicular to each other and spatially separated by assigning weights to received signals fed from the first, second, third and fourth receiving antennas

15   by using first and second received beam weights utilizing Fourier transform; a first path search section for measuring correlation between the first received beam fed from the received beam generating section and a known spreading code set for each of the individual mobile communication terminals, and for

20   outputting path information when the first received beam includes a signal spread by the spreading code; a second path search section for measuring correlation between the second received beam fed from the received beam generating section and a known spreading code set for each of the individual mobile

25   communication terminals, and for outputting path information when the second received beam includes a signal spread by the spreading code; and a demodulating section for receiving the first and second received beams from the received beam generating section, and for outputting demodulation data by performing RAKE

30   combining in response to the path information fed from the first

and second path search sections.

According to the present invention, the single demodulating section is enough for the demodulation processing for the four receiving antennas, which offers an advantage of being able to reduce the size of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing a configuration of a receiving apparatus in a radio communication apparatus of an embodiment 1 in accordance with the present invention;

FIG. 2 is a block diagram showing a configuration of a transmitting apparatus in the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 3 is a diagram showing a disposition of receiving antennas in the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 4 is a diagram showing a disposition of transmitting antennas in the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 5 is a chart showing radiation patterns of received beams beam0 and beam1 generated by a received beam generating section in the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 6 is a table showing a selecting method of the transmission beams by a feedback control section in the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 7 is a chart showing a radiation pattern of the transmission beam beam0 generated by the transmitting apparatus of the radio communication apparatus of the embodiment 1 in

accordance with the present invention;

FIG. 8 is a chart showing a radiation pattern of the transmission beam beam1 generated by the transmitting apparatus of the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 9 is a chart showing a radiation pattern of the transmission beam beam2 generated by the transmitting apparatus of the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 10 is a chart showing a radiation pattern of the transmission beam beam3 generated by the transmitting apparatus of the radio communication apparatus of the embodiment 1 in accordance with the present invention;

FIG. 11 is a chart showing phase characteristics of the received beam beam0 generated by the received beam generating section of the radio communication apparatus of the embodiment 1 in accordance with the present invention; and

FIG. 12 is a chart showing phase characteristics of the received beam beam1 generated by the received beam generating section of the radio communication apparatus of the embodiment 1 in accordance with the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

The best mode for carrying out the invention will now be described with reference to the accompanying drawings to explain the present invention in more detail.

EMBODIMENT 1

FIG. 1 is a block diagram showing a configuration of a receiving apparatus in a radio communication apparatus of an embodiment 1 in accordance with the present invention.

The radio communication apparatus, which comprises the receiving apparatus as shown in FIG. 1 and the transmitting apparatus as shown in FIG. 2, and carry out communication by receiving signals transmitted from mobile communication

5   terminals in the surrounding 360° range in the horizontal direction, is used for W-CDMA (Wideband Code Division Multiple Access) communication system, for example.

As shown in FIG. 1, the receiving apparatus of the radio communication apparatus includes four receiving antennas 11a,

10   11b, 11c and 11d (ant0, ant1, ant2 and ant3); a received beam generating section 12; path search sections 13 and 14; a feedback control section 15; a demodulating section 16; and a channel decoding section 17.

In FIG. 1, the receiving antennas 11a, 11b, 11c and 11d

15   receive incoming radio waves, and output received signals. The received beam generating section 12 assigns weights to the four received signals fed from the receiving antennas 11a, 11b, 11c and 11d by using received beam weights $W_{RXbeam0}$ and $W_{RXbeam1}$ using Fourier transform, thereby generating two received beams beam0

20   and beam1 which are perpendicular to each other and spatially separated.

The path search section 13, using the received beam beam0 from the received beam generating section 12 and a known spreading code that is set for each mobile communication terminal,

25   measures correlation, and outputs path information when the received beam beam0 includes the signal spread by a desired known spreading code. Likewise, the path search section 14, using the received beam beam1 from the received beam generating section 12 and the known spreading code that is set for each mobile

30   communication terminal, measures correlation, and outputs path

information when the received beam beam1 includes the signal spread by the desired known spreading code.

The feedback control section 15 selects a transmission beam to be transmitted according to the path information from the path search sections 13 and 14 and the phase difference between the received beam beam0 and received beam beam1 delivered from the demodulating section 16, and outputs selection information 101.

The demodulating section 16 accepts the received beams beam0 and beam1 fed from the received beam generating section 12, RAKE combines them according to the path information delivered from the feedback control section 15, and outputs demodulation data. In addition, the demodulating section 16 notifies the feedback control section 15 of the phase difference between the received beam beam0 and received beam beam1.

The channel decoding section 17 receives the demodulation data from the demodulating section 16, and carries out deinterleaving, rate dematching, error correction and the like.

The received beam generating section 12 includes multiplying sections 121a, 121b, 121c and 121d for assigning weights to the received signals from the receiving antennas 11a, 11b, 11c and 11d by multiplying them by weighting constants e^0, e^0, e^π and e^π, respectively; multiplying sections 122a, 122b, 122c and 122d for assigning weights to the received signals from the receiving antennas 11a, 11b, 11c and 11d by multiplying them by weighting constants e^0, e^π, e^π and e^0, respectively; a received signal combining section 123 for generating the received beam beam0 by combining the received signals weighted by the multiplying sections 121a, 121b, 121c and 121d; and a received signal combining section 124 for generating the received beam

beam1 by combining the received signals weighted by the multiplying sections 122a, 122b, 122c and 122d.

As shown in FIG. 2, the transmitting apparatus of the radio communication apparatus includes a spread modulating section 21, beam-by-beam multiplexing sections 22, 23, 24 and 25, transmission beam generating sections 26, 27, 28 and 29, a transmission multiplexing section 30, and four transmitting antennas 31a, 31b, 31c and 31d (ant0, ant1, ant2 and ant3).

In FIG. 2, the spread modulating section 21 receives user data to be transmitted to the individual mobile communication terminals, performs spreading processing using the spreading code set for each of the individual mobile communication terminals, and outputs spread data of the user.

The beam-by-beam multiplexing sections 22 and 23 receive the spread data of a plurality of users from a plurality of spread modulating sections 21, multiplex the spread data of the plurality of users in response to the selection information 101 from the feedback control section 15 on a transmission beam-by-transmission beam basis, and output the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d.

Likewise, the beam-by-beam multiplexing section 24 receives the spread data of the plurality of users from the plurality of spread modulating sections 21, multiplexes the spread data of the plurality of users in response to the selection information 101 on a transmission beam-by-transmission beam basis, and outputs the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a and 31c.

Likewise, the beam-by-beam multiplexing section 25 receives the spread data of the plurality of users from the plurality of spread modulating sections 21, multiplexes the spread data of the plurality of users in response to the selection information 101 on a transmission beam-by-transmission beam basis, and outputs the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31b and 31d.

The transmission beam generating sections 26 and 27 receive the spread data of the plurality of users passing through the multiplexing, which are output from the beam-by-beam multiplexing sections 22 and 23 in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d, assign weights to them by transmission beam weights $W_{TXbeam0}$ and $W_{TXbeam1}$, and output the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d.

Likewise, the transmission beam generating section 28 receives the spread data of the plurality of users passing through the multiplexing, which are output from the beam-by-beam multiplexing section 24 in correspondence with the individual transmitting antennas 31a and 31c, assigns weights to them by a transmission beam weight $W_{TXbeam2}$, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a and 31c.

Likewise, the transmission beam generating section 29 receives the spread data of the plurality of users passing through the multiplexing, which are output from the beam-by-beam multiplexing section 25 in correspondence with the individual

transmitting antennas 31b and 31d, assigns weights to them by
a transmission beam weight $W_{TXbeam3}$, and outputs the weighted spread
data of the plurality of users passing through the multiplexing
in correspondence with the individual transmitting antennas 31b

5   and 31d.

The transmission multiplexing section 30 receives the
weighted spread data of the plurality of users passing through
the multiplexing, which are output from the transmission beam
generating sections 26, 27, 28 and 29 in correspondence with

10   the individual transmitting antennas 31a, 31b, 31c and 31d,
multiplexes them on an antenna-by-antenna basis of the
transmitting antennas 31a, 31b, 31c and 31d, and supplies them
to the individual transmitting antennas 31a, 31b, 31c and 31d.

Here, the transmission beam generating section 26 includes

15   multiplying sections 261a, 261b, 261c and 261d for receiving
the spread data of the plurality of users passing through the
multiplexing output from the beam-by-beam multiplexing section
22 in correspondence with the transmitting antennas 31a, 31b,
31c and 31d, for assigning weights to them by multiplying the

20   weighting constants e^0, e^0, e^π and e^π, and for outputting the
weighted spread data of the plurality of users passing through
the multiplexing in correspondence with the transmitting
antennas 31a, 31b, 31c and 31d.

Likewise, the transmission beam generating section 27

25   includes multiplying sections 271a, 271b, 271c and 271d for
receiving the spread data of the plurality of users passing
through the multiplexing output from the beam-by-beam
multiplexing section 23 in correspondence with the transmitting
antennas 31a, 31b, 31c and 31d, for assigning weights to them

30   by multiplying the weighting constants e^0, e^π, e^π and e^0, and for

outputting the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antennas 31a, 31b, 31c and 31d.

Likewise, the transmission beam generating section 28 includes multiplying sections 281a and 281c for receiving the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 24 in correspondence with the transmitting antennas 31a and 31c, for assigning weights to them by multiplying the weighting constants $2e^0$ and $2e^\pi$, and for outputting the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antennas 31a and 31c.

Likewise, the transmission beam generating section 29 includes multiplying sections 291b and 291d for receiving the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 25 in correspondence with the transmitting antennas 31b and 31d, for assigning weights to them by multiplying the weighting constants $2e^0$ and $2e^\pi$, and for outputting the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antennas 31b and 31d.

The transmission multiplexing section 30 includes an antenna-by-antenna multiplexing section 301a for receiving the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27 and 28 in correspondence with the transmitting antenna 31a, for multiplexing them for the transmitting antenna 31a, and for supplying them to the transmitting antenna 31a; an antenna-by-antenna multiplexing section 301b for receiving the weighted spread data of the plurality of users passing

through the multiplexing output from the transmission beam
generating sections 26, 27 and 29 in correspondence with the
transmitting antenna 31b, for multiplexing them for the
transmitting antenna 31b, and for supplying them to the
5   transmitting antenna 31b; an antenna-by-antenna multiplexing
section 301c for receiving the weighted spread data of the
plurality of users passing through the multiplexing output from
the transmission beam generating sections 26, 27 and 28 in
correspondence with the transmitting antenna 31c, for
10   multiplexing them for the transmitting antenna 31c, and for
supplying them to the transmitting antenna 31c; and an
antenna-by-antenna multiplexing section 301d for receiving the
weighted spread data of the plurality of users passing through
the multiplexing output from the transmission beam generating
15   sections 26, 27 and 29 in correspondence with the transmitting
antenna 31d, for multiplexing them for the transmitting antenna
31d, and for supplying them to the transmitting antenna 31d.

FIG. 3 is a diagram showing a disposition of the receiving
antennas. The individual receiving antennas 11a, 11b, 11c and
20   11d (ant0, ant1, ant2 and ant3) are placed in the directions
0° , 90° , 180° and 270° at every $\lambda/2$ interval (λ is the
wavelength of the received radio wave).

FIG. 4 is a diagram showing a disposition of the
transmitting antennas. The individual transmitting antennas
25   31a, 31b, 31c and 31d (ant0, ant1, ant2 and ant3) are placed
in the directions 0° , 90° , 180° and 270° at every $\lambda/2$ interval
(λ is the wavelength of the transmitting radio wave) just as
the individual receiving antennas 11a, 11b, 11c and 11d.

Next, the operation of the receiving apparatus as shown
30   in FIG. 1 will be described.

The four receiving antennas 11a, 11b, 11c and 11d (ant0, ant1, ant2 and ant3) receive the incoming radio waves, and supply four received signals $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ to the received beam generating section 12.

5   The received beam generating section 12 assigns weights to the four received signals $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ fed from the individual receiving antennas 11a, 11b, 11c and 11d by using the received beam weights $W_{RXbeam0}$ and $W_{RXbeam1}$ using Fourier transform, generates the two received beams beam0 and beam1 which are

10   perpendicular to each other and spatially separated, and outputs them. The received beam weights $W_{RXbeam0}$ and $W_{RXbeam1}$ are used to generate the received beams beam0 and beam1 which are perpendicular to each other and spatially separated.

In the received beam generating section 12, the multiplying

15   sections 121a assigns the weight by multiplying the received signal $x_0(t)$ fed from the receiving antenna 11a by the weighting constant e^0; the multiplying sections 121b assigns the weight by multiplying the received signal $x_1(t)$ fed from the receiving antenna 11b by the weighting constant e^0; the multiplying

20   sections 121c assigns the weight by multiplying the received signal $x_2(t)$ fed from the receiving antenna 11c by the weighting constant e^{π}; and the multiplying sections 121d assigns the weight by multiplying the received signal $x_3(t)$ fed from the receiving antenna 11d by the weighting constant e^{π}.

25   Likewise, in the received beam generating section 12, the multiplying sections 122a assigns the weight by multiplying the received signal $x_0(t)$ fed from the receiving antenna 11a by the weighting constant e^0; the multiplying sections 122b assigns the weight by multiplying the received signal $x_1(t)$ fed from the

30   receiving antenna 11b by the weighting constant e^{π}; the

multiplying sections 122c assigns the weight by multiplying the received signal $x_2(t)$ fed from the receiving antenna 11c by the weighting constant e^π; and the multiplying sections 122d assigns the weight by multiplying the received signal $x_3(t)$ fed from the

5   receiving antenna 11d by the weighting constant e^0.

These multiplications can be easily implemented by code converters and adders.

Furthermore, in the received beam generating section 12, the received signal combining section 123 combines the received

10   signals $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ weighted by the multiplying sections 121a, 121b, 121c and 121d, thereby generating and outputting the received beam beam0. Likewise, the received signal combining section 124 combines the received signals $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ weighted by the multiplying sections 122a,

15   122b, 122c and 122d, thereby generating and outputting the received beam beam1.

The first received beam beam0 generated by the received beam generating section 12 has a radiation pattern with the major lobe in a certain direction and a grating lobe in the 180 degrees

20   opposite direction. The second received beam beam1 has a radiation pattern that is orthogonal to the first received beam beam0, and has the major lobe and grating lobe in a similar manner. Utilizing the grating lobes enables the single received beam to cover a 180° range in total, and the two received beams beam0

25   and beam1 to cover the 360° range in total. Thus, the received beam generating section 12 converts the four received signals $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ to the two received beams beam0 and beam1.

FIG. 5 is a chart showing the radiation patterns of the

30   received beams beam0 and beam1 generated by the received beam

generating section 12. When the receiving antennas 11a, 11b, 11c and 11d are disposed as shown in FIG. 3, the received beam beam0 has the radiation pattern with the major lobe and grating lobe in the directions 45° and 225°, and the received beam beam1 has the radiation pattern with the major lobe and grating lobe in the directions 135° and 315°. In this way, the received beam beam0 and received beam1 are perpendicular to each other and separated spatially, and have the radiation patterns with the directivity at every 90 degree interval according to the received beams beam0 and beam1.

In FIG. 5, numerical values "-20 to 10" on concentric circles of the radiation patterns indicate the gains (dB) of the antenna patterns. Here, 0 dB corresponds to the gain of a single receiving antenna, and combining the four receiving antennas 11a, 11b, 11c and 11d without loss quadruples the gain to 6 dB.

As shown in FIG. 5, the radiation patterns of the received beams beam0 and beam1 intersect with each other at 0°, 90°, 180° and 270°, and the gain of each radiation pattern is -2 dB at the intersection points with reference to the gain 0 dB of the single receiving antenna. In other words, at the intersection points, the gain of the received beams beam0 and beam1 output from the received beam generating section 12 reduces by 2 dB from the gain of the single receiving antenna. At the individual intersection points, a single input wave is received with being divided into the two received beams beam0 and beam1.

Next, the beam combining through two-dimensional Fourier transform in the received beam generating section 12 will be described.

The received signal X(t) of the receiving antenna 11 is

given by the following expression (1).

$$X(t) = [x_0(t) \ x_1(t) \ x_2(t) \ x_3(t)] \qquad (1)$$

where, $x_0(t)$, $x_1(t)$, $x_2(t)$ and $x_3(t)$ represent the received signals fed from the receiving antennas 11a, 11b, 11c and 11d, respectively, and t represents time.

The received beam weights $W_{RXbeam0}$ and $W_{RXbeam1}$ for generating the received beams beam0 and beam1 are given by the following expressions (2) and (3).

$$W_{RXbeam0} = [e^0 \ e^0 \ e^\pi \ e^\pi]^T \qquad (2)$$

$$W_{RXbeam1} = [e^0 \ e^\pi \ e^\pi \ e^0]^T \qquad (3)$$

where $[*]^T$ represents a transpose, the weighting constant e^0 represents a complex number "1 + j0" = 1, and the weighting constant e^π represents a complex number "-1 + j0" = -1.

Then, the received beams beam0 and beam1 are given by the following expressions (4) and (5).

$$beam0 = X(t) \cdot W_{RXbeam0} \qquad (4)$$

$$beam1 = X(t) \cdot W_{RXbeam1} \qquad (5)$$

The path search section 13 measures the correlation using the received beam beam0 fed from the received beam generating section 12 and the known spreading code set for each of the individual mobile communication terminals, and outputs, when the received beam beam0 includes the signal spread by the desired known spreading code, the path information including the received power and receiving timing. Likewise, the path search

section 14 measures the correlation using the received beam beam1 fed from the received beam generating section 12 and the known spreading code set for each of the individual mobile communication terminals, and outputs, when the received beam

5 beam1 includes the signal spread by the desired known spreading code, the path information including the received power and receiving timing.

The demodulating section 16, receiving the received beams beam0 and beam1 orthogonal to each other from the received beam

10 generating section 12, RAKE combines them in response to the path information given from the path search sections 13 and 14 via the feedback control section 15, and supplies the demodulation data to the channel decoding section 17. At the same time, the demodulating section 16 obtains the phase

15 difference between the received beam beam0 and received beam beam1 by carrying out the channel estimation using a receiving pilot signal, and notifies the feedback control section 15 of the phase difference.

The channel decoding section 17 receives the demodulation

20 data from the demodulating section 16, carries out deinterleaving, rate dematching, error correction and the like, and outputs the user data transmitted from the mobile communication terminal.

The feedback control section 15 selects the transmission

25 beam to be transmitted in response to the path information fed from the path search sections 13 and 14 and the information about the phase difference between received beam beam0 and received beam beam1 given by the demodulating section 16, and outputs the selection information 101.

30 FIG. 6 is a table showing a selecting method of the

transmission beam by the feedback control section 15.

FIG. 7 is a chart showing a radiation pattern of the transmission beam beam0 radiated from the transmitting apparatus. The radiation pattern has the directivity in the same directions as the received beam beam0, that is, the radiation pattern has the major lobe and grating lobe in the 45° direction and 225° direction.

FIG. 8 is a chart showing a radiation pattern of the transmission beam beam1 radiated from the transmitting apparatus. The radiation pattern has the directivity in the same directions as the received beam beam1, that is, the radiation pattern has the major lobe and grating lobe in the 135° direction and 315° direction.

FIG. 9 is a chart showing a radiation pattern of the transmission beam beam2 radiated from the transmitting apparatus. The radiation pattern has the directivity in the directions of the opposite intersection points of the received beams beam0 and beam1, that is, the radiation pattern has the major lobe and grating lobe in the 0° direction and 180° direction.

FIG. 10 is a chart showing a radiation pattern of the transmission beam beam3 radiated from the transmitting apparatus. The radiation pattern has the directivity in the directions 90 degrees shifted from the opposite intersection points of the received beams beam0 and beam1, that is, the radiation pattern has the major lobe and grating lobe in the 90° direction and 270° direction.

FIG. 11 is a chart showing phase characteristics of the received beam beam0 generated by the received beam generating section 12; and FIG. 12 is a chart showing phase characteristics of the received beam beam1 generated by the received beam

generating section 12.

As shown in FIG. 6, when the receiving path is found in the received beam beam0 in response to the path information fed from the path search section 13, the feedback control section 15 outputs the selection information 101 enabling the transmission beam beam0 shown in FIG. 7, which has the directivity in the same direction as the received beam beam0. Likewise, when the receiving path is found in the received beam beam1 in response to the path information fed from the path search section 14, the feedback control section 15 outputs the selection information 101 enabling the transmission beam beam1 shown in FIG. 8, which has the directivity in the same direction as the received beam beam1.

Furthermore, as shown in FIG. 6, when the receiving path is found in both the received beam beam0 and received beam beam1 in response to the path information fed from the path search section 13 and path search section 14, the feedback control section 15 selects the transmission beam to be transmitted in response to the information about the phase difference between the received beam beam0 and received beam beam1 given by the demodulating section 16. More specifically, when the receiving paths with the same delay in the received beam beam0 and received beam beam1 have the opposite phase with a phase difference of $180°$, the feedback control section 15 outputs the selection information 101 enabling the transmission beam beam2 that has the directivity in the direction of the intersection points of the received beams beam0 and beam1, that is, that has the major lobe and grating lobe in the $0°$ direction and $180°$ direction as shown in FIG. 9. On the other hand, when the receiving paths with the same delay in the received beam beam0 and received beam

beam1 have the same phase with a phase difference of $0°$, the feedback control section 15 outputs the selection information 101 enabling the transmission beam beam3 that has the directivity in the direction of the intersection points of the received beams

5   beam0 and beam1, which is shifted by 90 degrees from the transmission beam beam2, that is, that has the major lobe and grating lobe in the $90°$ direction and $270°$ direction as shown in FIG. 10.

     As shown in FIG. 5, the radiation patterns of the received

10   beam beam0 and received beam beam1 have the intersection points in the $0°$, $90°$, $180°$ and $270°$ directions. Thus, when the receiving paths are found in both the received beam beam0 and received beam beam1, this means that the incoming waves arrive from the foregoing angles. The phase characteristics of the

15   received beam 0 shown in FIG. 11 and the phase characteristics of the received beam 1 shown in FIG. 12 indicate that their phases are opposite in the $0°$ and $180°$ directions with the phase difference of $180°$, and that their phases are the same in the $90°$ and $270°$ directions with the phase difference of $0°$.

20   Accordingly, when the received beam beam0 and received beam beam1 have the opposite phases with the phase difference of $180°$, this means that the incoming waves arrive from the $0°$ or $180°$ direction. Thus, the feedback control section 15 outputs the selection information 101 enabling the transmission beam beam2

25   as shown in FIG. 9. On the other hand, when the received beam beam0 and received beam beam1 have the same phases with the phase difference of $0°$, this means that the incoming waves arrive from the $90°$ or $270°$ direction. Thus, the feedback control section 15 outputs the selection information 101 enabling the

30   transmission beam beam3 as shown in FIG. 10.

In this way, the feedback control section 15 selects the transmission beam that includes the direction of the incoming waves in which the mobile communication terminal of the user is present. Thus, it is not necessary for the transmitting apparatus to radiate all the transmission beams beam0, beam1, beam2 and beam3 in all the directions of 360° , thereby being able to reduce the transmitting power.

Next, the operation of the transmitting apparatus as shown in FIG. 2 will be described.

The spread modulating section 21 receives user data to be sent to individual mobile communication terminals fed from a channel coding section (not shown), carries out spreading processing using spreading codes that are set for the individual mobile communication terminals, and outputs spread data of the user.

The beam-by-beam multiplexing sections 22 and 23 receive spread data of a plurality of users fed from the spread modulating section 21 and other spread modulating sections (not shown), multiplex the spread data of the plurality of users for each transmission beam in response to the selection information 101 fed from the feedback control section 15 shown in FIG. 1, and output the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d. More specifically, when the selection information 101 fed from the feedback control section 15 is the information that enables the transmission beam beam0, the beam-by-beam multiplexing section 22 multiplexes and outputs the spread data of the user fed from the spread modulating section 21 that enables the transmission beam beam0 and the spread data of the users fed from the other spread modulating

sections that enable the transmission beam beam0; and when the selection information 101 fed from the feedback control section 15 is the information that enables the transmission beam beam1, the beam-by-beam multiplexing section 23 multiplexes and outputs the spread data of the user fed from the spread modulating section 21 that enables the transmission beam beam1 and the spread data of the users fed from the other spread modulating sections that enable the transmission beam beam1.

Likewise, the beam-by-beam multiplexing section 24 receives spread data of a plurality of users fed from a plurality of spread modulating sections 21, multiplexes the spread data of the plurality of users for each transmission beam in response to the selection information 101, and outputs the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a and 31c. More specifically, when the selection information 101 fed from the feedback control section 15 is the information that enables the transmission beam beam2, the beam-by-beam multiplexing section 24 multiplexes and outputs the spread data of the user fed from the spread modulating section 21 that enables the transmission beam beam2 and the spread data of the users fed from the other spread modulating sections that enable the transmission beam beam2.

Likewise, the beam-by-beam multiplexing section 25 receives spread data of a plurality of users fed from a plurality of spread modulating sections 21, multiplexes the spread data of the plurality of users for each transmission beam in response to the selection information 101, and outputs the spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31b

and 31d. More specifically, when the selection information 101 fed from the feedback control section 15 is the information that enables the transmission beam beam3, the beam-by-beam multiplexing section 25 multiplexes and outputs the spread data

5 of the user fed from the spread modulating section 21 that enables the transmission beam beam3 and the spread data of the users fed from the other spread modulating sections that enable the transmission beam beam3.

The transmission beam generating section 26 receives the

10 spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 22 in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d, assigns weights using the transmission beam weight $W_{TXbeam0}$, and outputs the weighted spread data of the

15 plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d.

Likewise, the transmission beam generating section 27 receives the spread data of the plurality of users passing

20 through the multiplexing output from the beam-by-beam multiplexing section 23 in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d, assigns weights using the transmission beam weight $W_{TXbeam1}$, and outputs the weighted spread data of the plurality of users passing through

25 the multiplexing in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d.

Likewise, the transmission beam generating section 28 receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam

30 multiplexing section 24 in correspondence with the individual

transmitting antennas 31a and 31c, assigns weights using the transmission beam weight $W_{TXbeam2}$; and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31a and 31c.

Likewise, the transmission beam generating section 29 receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 25 in correspondence with the individual transmitting antennas 31b and 31d, assigns weights using the transmission beam weight $W_{TXbeam3}$, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the individual transmitting antennas 31b and 31d.

The transmission beam weights $W_{TXbeam0}$, $W_{TXbeam1}$, $W_{TXbeam2}$ and $W_{TXbeam3}$ are used for generating the transmission beams beam0, beam1, beam2 and beam3 with the directivities in the directions as shown in FIG. 7, FIG. 8, FIG. 9 and FIG. 10.

The individual transmission beam weights $W_{TXbeam0}$, $W_{TXbeam1}$, $W_{TXbeam2}$ and $W_{TXbeam3}$ are expressed by the following expressions (6), (7), (8) and (9).

$$W_{TXbeam0} = [e^0 \ e^0 \ e^\pi \ e^\pi]^T \tag{6}$$

$$W_{TXbeam1} = [e^0 \ e^\pi \ e^\pi \ e^0]^T \tag{7}$$

$$W_{TXbeam2} = [2e^0 \ 0 \ 2e^\pi \ 0]^T \tag{8}$$

$$W_{TXbeam3} = [0 \ 2e^0 \ 0 \ 2e^\pi]^T \tag{9}$$

where $[*]^T$ represents a transpose, the weighting constant e^0 represents a complex number "1 + j0" = 1, the weighting constant e^π represents a complex number "-1 + j0" = -1, the weighting

constant $2e^0$ represents a complex number "2 + j0" = 2, and the weighting constant $2e^\pi$ represents a complex number "-2 + j0" = -2.

Here, in the transmission beam generating section 26, the multiplying section 261a receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 22 in correspondence with transmitting antenna 31a, assigns the weight by multiplying the weighting constant e^0, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31a.

Likewise, the multiplying section 261b receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 22 in correspondence with transmitting antenna 31b, assigns the weight by multiplying the weighting constant e^0, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31b.

Likewise, the multiplying section 261c receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 22 in correspondence with transmitting antenna 31c, assigns the weight by multiplying the weighting constant e^π, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31c.

Likewise, the multiplying section 261d receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 22 in

correspondence with transmitting antenna 31d, assigns the weight

by multiplying the weighting constant e^{π}, and outputs the

weighted spread data of the plurality of users passing through

the multiplexing in correspondence with the transmitting antenna

5   31d.

In addition, in the transmission beam generating section

27, the multiplying section 271a receives the spread data of

the plurality of users passing through the multiplexing output

from the beam-by-beam multiplexing section 23 in correspondence

10   with transmitting antenna 31a, assigns the weight by multiplying

the weighting constant e^0, and outputs the weighted spread data

of the plurality of users passing through the multiplexing in

correspondence with the transmitting antenna 31a.

Likewise, the multiplying section 271b receives the spread

15   data of the plurality of users passing through the multiplexing

output from the beam-by-beam multiplexing section 23 in

correspondence with transmitting antenna 31b, assigns the weight

by multiplying the weighting constant e^{π}, and outputs the

weighted spread data of the plurality of users passing through

20   the multiplexing in correspondence with the transmitting antenna

31b.

Likewise, the multiplying section 271c receives the spread

data of the plurality of users passing through the multiplexing

output from the beam-by-beam multiplexing section 23 in

25   correspondence with transmitting antenna 31c, assigns the weight

by multiplying the weighting constant e^{π}, and outputs the

weighted spread data of the plurality of users passing through

the multiplexing in correspondence with the transmitting antenna

31c.

30   Likewise, the multiplying section 271d receives the spread

data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 23 in correspondence with transmitting antenna 31d, assigns the weight by multiplying the weighting constant e^0, and outputs the

5   weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31d.

Furthermore, in the transmission beam generating section 28, the multiplying section 281a receives the spread data of

10   the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 24 in correspondence with transmitting antenna 31a, assigns the weight by multiplying the weighting constant $2e^0$, and outputs the weighted spread data of the plurality of users passing through the multiplexing in

15   correspondence with the transmitting antenna 31a.

Likewise, the multiplying section 281c receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 24 in correspondence with transmitting antenna 31c, assigns the weight

20   by multiplying the weighting constant $2e^{\pi}$, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31c.

Moreover, in the transmission beam generating section 29,

25   the multiplying section 291b receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 25 in correspondence with transmitting antenna 31b, assigns the weight by multiplying the weighting constant $2e^0$, and outputs the weighted spread data of

30   the plurality of users passing through the multiplexing in

correspondence with the transmitting antenna 31b.

Likewise, the multiplying section 291d receives the spread data of the plurality of users passing through the multiplexing output from the beam-by-beam multiplexing section 25 in correspondence with transmitting antenna 31d, assigns the weight by multiplying the weighting constant $2e^{\pi}$, and outputs the weighted spread data of the plurality of users passing through the multiplexing in correspondence with the transmitting antenna 31d.

These multiplications can be easily implemented by code converters and adders.

The transmission multiplexing section 30 receives the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27, 28 and 29 in correspondence with the individual transmitting antennas 31a, 31b, 31c and 31d, multiplexes them for each of the transmitting antennas 31a, 31b, 31c and 31d, and supplies to the individual transmitting antennas 31a, 31b, 31c and 31d.

In the transmission multiplexing section 30, the antenna-by-antenna multiplexing section 301a receives the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27 and 28 in correspondence with the transmitting antenna 31a, multiplexes them for the transmitting antenna 31a, and supplies to the transmitting antenna 31a.

Likewise, the antenna-by-antenna multiplexing section 301b receives the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27 and 29 in correspondence with

the transmitting antenna 31b, multiplexes them for the transmitting antenna 31b, and supplies to the transmitting antenna 31b.

Likewise, the antenna-by-antenna multiplexing section 301c receives the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27 and 28 in correspondence with the transmitting antenna 31c, multiplexes them for the transmitting antenna 31c, and supplies to the transmitting antenna 31c.

Likewise, the antenna-by-antenna multiplexing section 301d receives the weighted spread data of the plurality of users passing through the multiplexing output from the transmission beam generating sections 26, 27 and 29 in correspondence with the transmitting antenna 31d, multiplexes them for the transmitting antenna 31d, and supplies to the transmitting antenna 31d.

As described above, according to the present embodiment 1, the received beam generating section 12 generates the two received beams beam0 and beam1 which are perpendicular to each other and spatially separated by using the weights $W_{RXbeam0}$ and $W_{RXbeam1}$ using Fourier transform for the four received signals fed from the individual receiving antennas 11a, 11b, 11c and 11d. This makes it possible for the single demodulating section 16 to carry out the demodulation processing for the four receiving antennas 11a, 11b, 11c and 11d, thereby offering an advantage of being able to reduce the size of the apparatus as compared with the conventional radio communication apparatus that requires the demodulating sections of the same number as the receiving antennas.

In addition, the present embodiment 1 can detect the path information from the two received beams beam0 and beam1 generated, reduce the number of the path search sections, and reduce the number of the inputs to the demodulating section 16 to two.

5   Accordingly, the present embodiment 1 can reduce the input switching function in the demodulating section 16, thereby offering an advantage of being able to miniaturize the apparatus.

Furthermore, the present embodiment 1 generates the two received beams beam0 and beam1, and supplies the demodulating

10   section 16 with the received signal having the antenna gain four times greater than that of a single receiving antenna, thereby offering an advantage of being able to improve the receiving performance.

Moreover, according to the present embodiment 1, the

15   receiving apparatus detects the path information from the received beams beam0 and beam1, and selects the transmission beam including the arrival direction of the incoming waves; and the transmitting apparatus radiates the transmission beam selected. This offers an advantage of being able to reduce the

20   transmitting power.

Although the present embodiment 1 employs the four receiving antennas 11a, 11b, 11c and 11d, this is not essential. For example, a diversity configuration is also possible by adding four other receiving antennas, in which case the signals fed

25   from the eight antennas can be converted into four received beams. In addition, providing receiving antennas in such a manner as to compensate for the reductions between the received beams offers an advantage of being able to improve the receiving characteristics.

30   In addition, although the present embodiment 1 multiplexes

the spread data of the plurality of users into the transmission beams beam0, beam1, beam2 and beam3, and transmits them from the four transmitting antennas 31a, 31b, 31c and 31d, this is not essential. For example, they can be transmitted using a single nondirectional transmitting antenna without carrying out the beam combining.

INDUSTRIAL APPLICABILITY

As described above, the radio communication apparatus in accordance with the present invention is suitable for miniaturizing the apparatus by reducing the number of the demodulating sections in comparison with the number of the receiving antennas.